REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
09/04/96

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Digitization and Reanalysis of Analog Sonobuoy Records

5. FUNDING NUMBERS
N00014-93-1-0346

6. AUTHOR(S)
Dr. John B. Diebold

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
The Trustees of Columbia University
in the City of New York
1210 Amsterdam Avenue, MC 2205
New York, NY 10027

8. PERFORMING ORGANIZATION REPORT NUMBER
5-21720

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
Ballston Tower One
800 North Quincy St.
Arlington, VA 22217-5660

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Most published information on age-dependent changes in the physical properties of upper oceanic crust (layer 2A) was based on the interpretation of analog airgun-sonobuoy records. New technology, developed at Lamont during an earlier ONR-funded project, allows digitization (via scanning) and computer-based analysis, via interactive ray tracing. The digitization process was applied to 142 analog records from sonobuoys located on Pacific ocean crust with well determined ages between zero and 10 my. Initial analysis was begun, and the records were evaluated and sorted into three categories depending on whether the necessary arrivals for 2A velocity determination were present. 50 = "yes", 55 = "maybe", 37 = "no". At this point, funding was withdrawn due to the termination of the crustal evolution project and reassignment of its program manager.

14. SUBJECT TERMS
examination and reanalysis of sonobuoy records

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

GENERAL INSTRUCTIONS FOR COMPLETING SF 298

The Report Documentation Page (RDP) is used in announcing and cataloging reports. It is important that this information be consistent with the rest of the report, particularly the cover and title page. Instructions for filling in each block of the form follow. It is important to ***stay within the lines*** to meet ***optical scanning requirements.***

Block 1. Agency Use Only *(Leave blank)*.

Block 2. Report Date. Full publication date including day, month, and year, if available (e.g. 1 Jan 88). Must cite at least the year.

Block 3. Type of Report and Dates Covered. State whether report is interim, final, etc. If applicable, enter inclusive report dates (e.g. 10 Jun 87 - 30 Jun 88).

Block 4. Title and Subtitle. A title is taken from the part of the report that provides the most meaningful and complete information. When a report is prepared in more than one volume, repeat the primary title, add volume number, and include subtitle for the specific volume. On classified documents enter the title classification in parentheses.

Block 5. Funding Numbers. To include contract and grant numbers; may include program element number(s), project number(s), task number(s), and work unit number(s). Use the following labels:

C	Contract	PR	Project
G	Grant	TA	Task
PE	Program Element	WU	Work Unit Accession No.

Block 6. Author(s). Name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. If editor or compiler, this should follow the name(s).

Block 7. Performing Organization Name(s) and Address(es). Self-explanatory.

Block 8. Performing Organization Report Number. Enter the unique alphanumeric report number(s) assigned by the organization performing the report.

Block 9. Sponsoring/Monitoring Agency Name(s) and Address(es). Self-explanatory.

Block 10. Sponsoring/Monitoring Agency Report Number. *(If known)*

Block 11. Supplementary Notes. Enter information not included elsewhere such as: Prepared in cooperation with...; Trans. of...; To be published in.... When a report is revised, include a statement whether the new report supersedes or supplements the older report.

Block 12a. Distribution/Availability Statement. Denotes public availability or limitations. Cite any availability to the public. Enter additional limitations or special markings in all capitals (e.g. NOFORN, REL, ITAR).

DOD - See DoDD 5230.24, "Distribution Statements on Technical Documents."
DOE - See authorities.
NASA - See Handbook NHB 2200.2.
NTIS - Leave blank.

Block 12b. Distribution Code.

DOD - Leave blank.
DOE - Enter DOE distribution categories from the Standard Distribution for Unclassified Scientific and Technical Reports.
NASA - Leave blank.
NTIS - Leave blank.

Block 13. Abstract. Include a brief *(Maximum 200 words)* factual summary of the most significant information contained in the report.

Block 14. Subject Terms. Keywords or phrases identifying major subjects in the report.

Block 15. Number of Pages. Enter the total number of pages.

Block 16. Price Code. Enter appropriate price code *(NTIS only)*.

Blocks 17. - 19. Security Classifications. Self-explanatory. Enter U.S. Security Classification in accordance with U.S. Security Regulations (i.e., UNCLASSIFIED). If form contains classified information, stamp classification on the top and bottom of the page.

Block 20. Limitation of Abstract. This block must be completed to assign a limitation to the abstract. Enter either UL (unlimited) or SAR (same as report). An entry in this block is necessary if the abstract is to be limited. If blank, the abstract is assumed to be unlimited.

Standard Form 298 Back (Rev. 2-89)

Lamont-Doherty
Earth Observatory
of Columbia University

P.O. BOX 1000 / RT 9W / PALISADES. NY 10964-8000 USA / 914-359-2900

March 15, 1996

Dr. Joseph Kravitz, Program Officer
Office of Naval Research
Code 322GG
800 N. Quincy St.
Arlington, VA 22217-5660

Re: FINAL TECHNICAL REPORT for -
Digitization and Reanalysis of Analog Sonobuoy Records,
Continuation of ONR Grant NOOO14-93-1-0346

Dear Joe:

Enclosed is the Final Technical Report concerning the above-mentioned grant.

If you require any further information, please do not hesitate to contact me.

Very truly yours,

John B. Diebold

enclosures

cc: Mr. Martin Morris, Resident Rep., Boston, MA
Director - Naval Research Lab, Washington, DC
✓Defense Technical Information Center, Alexandria, VA
Columbia University - Office of Projects & Grants
P. Stambaugh, Sr. Contracts Officer, Lamont-Doherty

Digitization and Re-Analysis of Analog Sonobuoy Records

Final Report

John Diebold
Lamont-Doherty Earth Observatory of Columbia University
Palisades NY 10964-8000
johnd@ldeo.columbia.edu
(914)365-8524; Fax 3181

Long Term Scientific Objectives

The physical properties and, therefore, the wave propagation characteristics of upper oceanic crust change drastically within the first few millions of years after creation. The rate at which this change occurs and the processes involved are not well known. More detailed knowledge of the former will obviously be a great help in determining the process of upper crustal alteration. The upper layer of oceanic crust was first identified by seismic refraction at the Reykjanes Ridge, and named "2A" (Talwani, et al., 1971). In two journal articles published in 1976, Houtz & Ewing and Houtz presented results of sonobuoy analysis indicating that the velocity of uppermost oceanic crust increased from around 3.3 km/sec to approximately 5.5 km/sec during its first 30 my of age, and that the apparent thickness of 2A decreased from about 800 meters to almost zero during the same time interval. More recent results, from two-ship Multichannel seismic data and ODP drilling, indicate that Houtz & Ewing were overly conservative in their estimate of the range over which 2A velocities may vary.

Project Objectives

The first part of this study involved the examination and reanalysis of the sonobuoy records used by Houtz (1976). These included 20 buoys with crustal ages between zero and ten my, in which Houtz identified layer 2A arrivals. The objective of the 1994-95 phase of the sonobuoy reanalysis project was to continue the analysis of analog sonobuoy data, examining a larger suite of records from well-dated crust, in hopes of increasing the population of 2A velocity results in the 0 - 10my age range.

Final Status

Locations for the some 4200 sonobuoys whose analog records are archived at L-DEO were compared with the ocean floor age database prepared by Mueller, et al. (1993); 2190 buoys were found to be situated over reliably dated sea floor. Of these, 190 fell within the 0 - 10 my range, and 142 of those were shot in the eastern Pacific. The original analog records for most of these 142 buoys were extracted from the data archive and scanned at 200 dpi. Each sonobuoy provided as many as three images -- two data channels and the coincident single channel seismic vertical profile. In addition, 35 digitally recorded buoys from the ROSE area were rasterized, and an additional 40 buoys were recorded during the Gorda Ridge Transect, reported upon elsewhere in this volume. The total number of sonobuoys in young Pacific crust comprised by

this database is now slightly over 200 (Figure 1). Excepting the just-acquired 40 Gorda Ridge buoys, all of the records have been interactively modeled to obtain range and time scaling parameters, and roughly sorted into three categories (yes, no, maybe) according to the visual appearance of 2A arrivals. Fifty buoys fall into the "yes" category, fifty-five, "maybe". Some of these records have been carefully analyzed during the course of the first stage of this effort, but much more work remains to be done before the fruits of this newly amassed database can be fully exploited. Unfortunately, the curtailment of the ONR crustal evolution project and the associated cancellation of the second year of this project has prevented further progress.

References

Houtz, R. and J. Ewing, 1976. Upper Crustal Structure as a function of Plate Age; JGR, **81**, p. 2490-2498.

Houtz, R. E., 1976. Seismic Properties of Layer 2A in the Pacific; JGR, **81**, p. 6321-6331.

Mueller, R.D., W.R. Roest, J-Y Royer, L.M Gahagan, and J.G. Sclater, 1993. A Digital Age Map of the Ocean Floor; SIO Reference Series No. 93-30.

Talwani, M., C. C. Windisch, and M. G. Langseth, 1971. Reykjanes Ridge Crest: A Detailed Geophysical Study; JGR, **76**, p. 473-517.

Publications

Diebold, J. , and R. Carlson, Layer 2A Revisited, *EOS Trans. AGU, 74* (43), Fall Meeting suppl., 603, 1993.

Jacobson, R., J. Diebold, and R. Carlson, Digitization and Reanalysis of Analog Airgun-Sonobuoy Records, *EOS Trans. AGU, 74* (43), Fall Meeting suppl., 451, 1993.

APPENDIX

Below is a working list of Pacific Ocean analog sonobuoy records that have been digitized via scanning, and examined for layer 2A arrivals. Entries in the fourth column are: "H" = included in the Houtz, Houtz & Ewing (1976) study; "H*" = identified by Houtz as having a 2A arrival. Age was calculated from the Mueller, et. al. (1993) database. "Comments" are my notes, which I was using as sorting criteria.

Buoy	Lon	Lat		Age	Depth	Comments
101V28	-91.8810	3.8210	H	4.660	2.950	yes - weak
102V28	-91.7540	3.7680	H*	4.590	2.897	4.0? Houtz 3.9
104V28	-94.7620	4.8460		5.430	3.112	topo
105V28	-95.2470	5.3190		6.260	3.544	"B" = yes
106V28	-97.3090	6.3750		7.280	3.464	poss. weak buoy
108V28	-102.7700	9.0460		1.960	3.219	no
109V28	-102.0090	10.0910		4.520	3.449	yes-A
10C13	-111.3790	-17.3900	H	2.050	3.375	topo, refl & shear
10C22	-103.3700	12.1000		1.150	3.082	missing traces
11C13	-113.2710	-17.4120	H	0.050	3.015	yes
11C22						refl & topo
12C13	-115.2370	-17.3540	H*	2.740	3.293	B - wrong buoy? H. 3.9
12C22	-103.6000	12.0900		0.970	2.648	yes
13C13	-112.0010	-17.1680	H	1.360	3.195	yes!
13C22						topo, but maybe
14C13	-113.4140	-17.0290	H	0.310	2.963	refl
15C13	-113.8240	-18.0560	H	0.710	2.993	refl
16C13	-113.3560	-18.1800		0.130	2.678	ringy pos. 2A, shear
170V32						topo but yes..
17C13	-113.2710	-17.6080	H	0.110	2.760	refl & shear
19C13	-112.7370	-17.6250		0.670	3.082	refl
1C22	-102.0000	12.2800		4.340	3.150	no
204C21	-76.1800	-48.4900		9.260	1.507	yes
22C13	-111.8130	-17.7110		1.680	3.225	yes
23C13	-111.8040	-17.5730		1.630	3.473	yes
24C13	-112.2330	-18.1980	H	1.300	3.173	topo
24C22	-102.0200	12.6400		4.480	3.233	weak refl
25C13	-113.4350	-18.1970		0.130	2.955	topo weak refl
25C22	-101.9800	12.3000		4.340	3.158	topo but maybe
26C13	-114.0130	-18.1980	H	0.920	3.038	topo but maybe
26C22						topo
27C13	-115.1680	-18.3260	H*	2.590	3.225	shear no 2A Houtz 3.25
27C22	-101.9400	11.9300		4.320	3.188	no
28C13	-113.7710	-18.4160		0.670	2.925	poor refl
28C22	-101.9000	11.6300		4.020	3.247	topo - refl
29C13	-112.1630	-18.4050	H	1.250	3.180	topo
29C22	-101.8600	11.4200		3.880	3.092	weak refraction?
2C22						topo
30C22	-102.0200	11.1800		3.100	3.307	topo but sorta refl
31C22	-102.6500	11.1700		1.940	3.135	thin 2A weak + shear
32C22	-102.7600	11.7200		1.870	2.805	fuzzy
33C22	-102.7800	12.0800		1.910	2.970	??
35C22	-102.7800	12.6700		2.010	2.762	topo maybe refrac.
36C22	-103.7800	13.0300		0.930	2.985	possible weak refrac.
37C22						bad buoy

38C22	-103.5800	11.4000		0.940	2.985	topo but refl
39C13	-106.9450	0.7800	H	5.160	3.652	weak buoy but refrac?
39C22	-104.1700	11.4000		0.400	3.000	shear no 2A
3C22						topo but maybe
40C13	-107.2510	3.5690		3.380	3.855	bad topo
40C22	-104.2100	11.7500		0.360	3.060	topo
416C21	-83.8500	2.7200		1.490	3.210	refrac??
417C21	-83.8600	2.3800		2.040	3.225	topo no data
418C21						short, maybe refrac
419C21	-83.8400	1.9600		3.790	3.443	refrac
41C13	-106.8760	12.7600		2.810	3.443	topo but maybe
41C22	-104.2500	12.0900		0.370	3.113	possible weak refrac
420C21	-83.8500	1.6600		4.770	3.233	refrac
421C21	-83.8700	1.3500		5.690	3.450	yes!
422C21	-83.8700	0.9700		7.770	3.476	weak refrac pos. refl.
423C21	where is it?					yes!
424C21	-83.6100	1.1700		6.560	3.383	yes! and good shear
425C21	-83.7600	1.1400		7.190	3.480	Topo, good 2B shear
426C21	-83.7800	1.4900		5.280	3.473	refl ? weak refrac
427C21	-83.7500	1.8900		4.170	3.450	ditto + topo
428C21	-84.0100	1.9000		4.330	3.398	topo weak refrac
429C21	-83.7400	1.6800		4.740	3.150	hard to see
42C13	-103.9960	12.8900	H	0.930	2.678	no data no arrival
42C22	-104.2900	12.4300		0.400	3.188	weak refl
430C21	-83.8800	1.5100		5.310	3.420	need sed thickness
431C21	-83.7100	1.3900		5.620	3.548	weak + topo
43C13	-103.9360	12.6030	H*	0.930	2.655	weak refrac (?) H. 3.6
43C22						no
44C13	-103.6890	12.8900	H*	0.960	3.015	weird arrival Houtz 3.2
44C22	-103.9500	12.3300		0.050	2.872	weak refl
45C13	-103.4820	12.8930	H*	1.180	2.850	refl? need sed. thick.
45C22	-104.1800	11.9900		0.400	3.165	weak refl - weak shear
46C13	-103.4470	12.7340		1.340	3.082	refl, refrac, but a gap
46C22	-103.9200	12.0100		0.100	2.918	topo
47C13	-103.4690	12.8420		1.170	3.165	topo
47C22	-103.6700	12.0500		0.950	2.993	topo
48C13	-103.3590	12.8430	H*	1.360	3.090	topo but yes Houtz 3.3
48C22	-103.3500	12.0700		1.320	3.000	topo
49C13	-103.1450	12.8410		1.830	3.023	bad buoy
49C18	-76.0740	-44.6600		6.120	3.288	Yes! max sediment
49C20	-103.5130	9.3850		1.620	3.158	topo weak ref, 2B shear
49C22	-103.0600	12.0900		1.670	3.015	topo
4C22	-102.4300	12.2200		2.360	3.142	poss. weak refraction
50C13	-102.8000	12.8400	H	2.010	3.068	ditto
50C22	-102.7600	12.1000		1.910	3.075	topo but refl?
51C13	-103.8450	12.6690		0.940	2.850	yes
51C20	-103.7310	9.3480		1.240	3.128	?
51C22	-102.5100	12.0900		2.080	3.120	topo but emerging ref
52C13						no
52C20	-105.7290	9.0840		1.330	3.293	shear (?)
52C22	-102.2300	12.1600		3.240	3.188	topo, poss. shear
53C13	-103.9000	12.6000	H*	0.930	2.640	bad buoy Houtz 3.4
53C20	-105.9590	9.0380		1.590	3.405	topo poss.emergent
53C22						topo + poss. emerging
54C13	-103.9700	12.8510	H*	0.930	2.685	hard to see it H. 4.15
54C20	-105.3270	8.7440		0.900	3.142	topo
55C13	-103.8130	12.6370	H	0.940	2.977	yes
55C18	-94.4230	-40.9890		6.970	3.480	topo

55C20	-105.2700	9.1490		0.950	3.240	yes!
56C13	-103.7930	12.4540	H	0.940	2.925	poss. weak buoy
57C13	-103.8320	12.7880	H	0.940	2.963	yes!
57V32	-99.7580	13.1670		9.430	3.608	no + thick 2A
58C13	-103.4990	12.8000	H*	1.170	2.947	no Houtz 2.8
58V32			H*			no Houtz 3.7
59C13	-103.2160	12.8090		1.720	3.075	topo, but ?
59V32	-98.556	14.850	H	10.600	3.413	963 no have
5C22						topo, poss. refl
60C13	-102.9420	12.8120	H*	1.950	3.068	yes Houtz 3.75
61C13	-102.7050	12.7900	H	2.090	3.098	yes
62C13	-102.6450	12.5220	H*	2.240	3.142	poss. emerg. ref.H. 3.9
62V32	-99.122	14.751	H	10.600	3.675	973 no have
63V32	-100.5860	12.6000	H*	6.720	3.473	yes! Houtz 4.2
64C13	-102.3680	12.7320	H	2.900	3.300	yes
64V32	-100.4260	14.2030	H	9.140	3.525	possible refr. need sed
65C13	-102.0360	12.7100	H	4.510	3.322	yes
66C13	-101.9950	12.4170	H	4.410	3.060	yes
66V32	-106.9000	2.9780		3.160	3.803	yes -.215s seds
67C13	-102.0450	12.7030	H*	4.510	3.300	topo H. 3.3
67V32						topo, poss. refr
68C13	-101.7020	12.7030	H	4.760	3.330	topo
68V32	-109.4480	3.0570		4.840	3.855	topo, poss.2A
6C22	-102.7200	12.1800		1.980	3.075	refl?
70C13	-101.2090	12.6910	H	4.980	3.322	topo
70V32	-110.7100	2.7080		5.800	3.780	topo weak refrac
71C13	-100.8140	12.6790	H	6.150	3.375	yes
71V32	-112.5800	2.6910		7.160	3.878	topo shear only
72C13	-100.7640	12.3810	H	5.680	3.398	refl
73C13	-100.8460	12.7070	H	6.150	3.247	topo
73V32	-114.0080	2.7010	H	8.190	3.797	topo possible refrac
74V32	-114.5230	2.7060	H	8.570	3.848	?
75C13	-101.5810	12.6840	H	4.800	3.113	yes but topo
75V32	-114.7510	2.6960	H*	8.850	3.894	yes but topo Houtz 3.85
76C13	-101.5390	12.3700	H*	4.790	3.315	maybe need sed thick.
77C13	-102.3690	12.3290	H	2.510	3.068	no
77V32			H*			topo, maybe - Houtz 3.7
78C13	-102.3770	12.4340	H	2.650	3.173	refl maybe
78V32	-119.037	2.668	H	18.640	4.275	1095 no have
79C13	-103.0060	12.4340	H*	1.860	3.053	topo maybe Houtz 3.5
7C22						topo
80C13	-103.0610	12.5030	H	1.800	3.105	no
81C13	-101.0630	12.2440	H	4.890	3.293	very weak arrivals
82C13	-99.140	12.822	H	10.170	3.503	1035 no have
85C13	-97.982	12.500	H	10.570	3.570	1043 no have
86C13	-92.9070	7.6030		9.730	3.630	yes
87C13	-92.1320	6.8940		9.070	3.562	no
89C13						bad buoy
8C13						maybe refrac need sed Z
8C22	-103.0600	12.1400		1.670	3.060	maybe emerging refrac
90C13	-87.9520	2.9910		4.500	1.043	yes!
90V32						poss.refrac very weak
91V32						no - good 2B
92C11	-127.2280	47.8960		2.200	2.551	this series hard to see
93C11	-127.3840	47.8590		1.930	2.585	top of crust - thin 2A
94C11	-127.5850	47.8110		1.650	2.599	no
95C11	-127.8520	47.7590		1.260	2.605	shear poss. 2A
96C11	-128.0930	47.7040		0.990	2.648	best of these

98V28	-85.2780	6.3570		9.920	1.891	poss 2A buried in 2B
9C13	-114.2340	-17.5980	H*	1.300	3.150	shear Houtz 2.95 no 2B
9C22	-103.1500	12.1300		1.670	3.188	no